IN THE CLAIMS

1 1.   (currently amended) A method of determining diffusion and relaxation

2   characteristics about a fluid in an earth formation using nuclear magnetic

3   resonance (NMR) comprising:

4   (a)   applying a static magnetic field to the earth formation, said applied

5   static magnetic field producing an internal field gradient;

6   (b)   applying a sequence of radio frequency (RF) pulses to said earth

7   formation;

8   (c)   detecting magnetic resonance signals resulting from said first sequence,

9   substantially all of said magnetic resonance signals being affected by the

10   internal field gradient; and

11   (d)   processing said detected signals for determining said diffusion and

12   relaxation characteristics, said determination taking into

13   account said internal field gradient.

14

1 2.   (currently amended) The method of claim 1 wherein said sequence of RF pulses

2   further comprises:

3   (A)   a first sequence of RF pulses associated with a first signal at a first field

4   gradient, and

5   (B)   a second sequence of RF pulses associated with a second signal at a

6   second field gradient different from said first field gradient;

7   wherein said detected signals comprise said first signal and said second signal..

8

1 3.   (original) The method of claim 2 wherein said first and second field gradients

2   correspond to different regions of examination in said earth formation.

3

1 4.   (original) The method of claim 2 wherein said first and second pulse sequences

2   each comprise at least one initial pulse, a first portion that follows the at least one

3   initial magnetic field pulse, and a second portion that follows the first portion

4   such that the second portion refocuses a last echo of the first portion.

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1 5.   (original) The method of claim 2 wherein

2   (i)   said first portion comprises a modified CPMG sequence including a

3   plurality of refocusing pulses with a tipping angle less than 180^0 and

4   having a first time interval between adjacent refocusing pulses of said

5   first portion, and

6   (ii)   said second portion comprises a plurality of refocusing pulses having a

7   second time interval between adjacent refocusing pulses.

8

1 6.   (original) The method of claim 2 wherein said first portion comprises one of (i) an

2   inversion recovery sequence, (ii) a driven equilibrium sequence, and, (iii) a

3   CPMG sequence.

4

1 7.   (original) The method of claim 5 further comprising applying an echo train

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2   correction to said first and second signal.

3

1   8.   (original) The method of claim 5 further comprising at least one additional

2   repetition of (A) and (B) for a different value of said first time interval.

3

1   9.   (original) The method of claim 5 further comprising repeating (i) for at least one

2   additional value of a time interval between refocusing pulses of said CPMG

3   sequence, said additional value being substantially equal to said second time

4   interval.

5

1   10. (original) The method of claim 1 further determining at least one of (i) a total

2   porosity, (ii) clay bound water, (iii) bound volume irreducible, (iv) gas saturation,

3   and (v) oil saturation.

4

1   11. (original) The method of claim 2 wherein said first sequence is of a form:

$$W - 90_{\pm x} - TE_{long}/2 - \beta_{Y1} - TE_{long}/2 - echo_1 - TE_{long}/2 - \beta_{Y1}$$
$$- TE_{long}/2 - echo_2 - (TE/2 - \beta_{Y2} - TE/2 - echo)_j$$

2

3   where j is an echo number in a train, W is a wait time, TE_{long} is a diffusion editing

4   spacing, TE is the Carr-Purcell spacing, $90_{\pm x}$ and β_{Y1} (or β_{Y2}) are RF pulses

5   providing rotation angles of 90 and the β_{Y1}(or β_{Y2}) degrees of a magnetization

6   vector.

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1   12.   (currently amended) The method of ~~claim 1~~ claim 2 wherein processing said ~~first~~

2   ~~and said second signal~~ detected signals further comprises, for said first field

3   gradient and said second gradient, inverting said first and said second signals, to

4   obtain an equivalent amplitude spectrum of a T_2 distribution.

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1   13.   (currently amended) The method of claim 12 wherein said processing said ~~first~~

2   ~~and said second signal~~ detected signals further comprises inverting a T_2

3   distribution to obtain a generalized parameter.

4

1   14.   (original) The method of claim 13 wherein said generalized parameter $Z_i^{(j)}$ has a

2   form:

3

4         $$Z_i^{(j)} = \frac{C}{\gamma^2 G_e^2 D_i^j}$$

5   where C is a constant, γ is a gyromagnetic ratio, G_e is the effective field

6   gradient, and D_i^j is a diffusion coefficient.

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1   15.   (currently amended) The method of claim 13 wherein said processing said ~~first~~

2   ~~and said at least one additional signal~~ detected signals further comprises inverting

3   a plurality of said generalized parameters.

4

1   16.   (original) The method of claim 12 wherein at least one component of said

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2   equivalent amplitude spectrum further comprises a plurality of diffusion

3   components.

4

1   17.   (original) The method of claim 11 further comprising at least one additional

2   repetition of (b) and (c) for a different value of TE_{long}.

3

1   18.   (original) The method of claim 2 wherein said first pulse sequence is of a form:

2        $$180 - \tau_1 - 90_{\pm x} - \left[TE/2 - \beta_Y - TE/2 - echo \right]_j$$

3   wherein 180 is a 180^0 tipping pulse, τ is a wait time, TE is the Carr-Purcell

4   spacing, $90_{\pm x}$ and β_Y are RF pulses providing rotation angles of 90^0 and β of

5   a magnetization vector

6

1   19.   (original) The method of claim 18 further comprising at least one additional

2   repetition of (A) and (B) for a different value of τ.

3

1   20.   (currently amended) An apparatus for determining diffusion and relaxation

2   characteristics about a fluid in an earth formation comprising:

3   (a)   a magnet on a nuclear magnetic resonance (NMR) sensor conveyed in a

4   borehole in said earth formation, said magnet producing a static magnetic

5   field to in the earth formation with an internal field gradient therein;

6   (b)   a transmitter on said NMR sensor for applying which applies a sequence

7   of radio frequency (RF) pulses to said earth formation;

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8   (c)   a receiver on said NMR sensor ~~for detecting~~ which detects magnetic

9   resonance signals resulting from said first sequence, substantially all of the

10   magnetic resonance signals being affected by the internal field gradient;

11   and

12   (d)   a processor ~~for determining~~ which determines from said detected signals

13   said diffusion and relaxation characteristics, said determination taking into

14   account said internal field gradient.

15

1   21.   (currently amended) The apparatus of claim 20 wherein said transmitter applies:

2   (A)   a first sequence of RF pulses associated with a first signal at a first field

3   gradient, and

4   (B)   a second sequence of RF pulses associated with a second signal at a

5   second field gradient different from said first field gradient;

6   wherein said magnetic resonance signals comprise said first signal and said

7   second signal.

8

1   22.   (original) The apparatus of claim 21 wherein said first and second field gradients

2   correspond to different regions of examination in said earth formation.

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1   23.   (currently amended) The apparatus of claim 21 wherein said first sequence of RF

2   pulses and the second sequence of RF pulses ~~pulse sequences~~ each comprise at

3   least one initial pulse, a first portion that follows the at least one initial magnetic

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4   field pulse, and a second portion that follows the first portion such that the second

5   portion refocuses a last echo of the first portion.

6

1   24.   (currently amended) The apparatus of ~~claim 21~~ claim 23 wherein

2   (i)   said first portion comprises a modified CPMG sequence including a

3   plurality of refocusing pulses with a tipping angle less than 180^0 and

4   having a first time interval between adjacent refocusing pulses of said

5   first portion, and

6   (ii)   said second portion comprises a plurality of refocusing pulses having a

7   second time interval between adjacent refocusing pulses.

8

1   25.   (currently amended) The apparatus of ~~claim 21~~ claim 23 wherein said first portion

2   comprises one of (i) an inversion recovery sequence, (ii) a driven equilibrium

3   sequence, and (iii) a CPMG sequence.

4

1   26.   (original) The apparatus of claim 24 wherein said processor further applies further

2   an echo train correction to said first and second signal.

3

1   27.   (original) The apparatus of claim 24 wherein said transmitter further performs at

2   least one additional repetition of (A) and (B) for a different value of said first time

3   interval.

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1 28. (original) The apparatus of claim 24 wherein said processor further repeats (i) for

2   at least one additional value of a time interval between refocusing pulses of said

3   CPMG sequence, said additional value being substantially equal to said second

4   time interval.

5

1 29   (original) The apparatus of claim 20 wherein said processor further determines at

2   least one of (i) a total porosity, (ii) clay bound water, (iii) bound volume

3   irreducible, (iv) gas saturation, and, (v) oil saturation.

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1 30. (original) The apparatus of claim 21 wherein said first sequence is of a form:

$$W - 90_{\pm x} - TE_{long}/2 - \beta_Y - TE_{long}/2 - echo_1 - TE_{long}/2 - \beta_Y$$
$$- TE_{long}/2 - echo_2 - \left(TE/2 - \beta_Y - TE/2 - echo\right)_j$$

2

3   where j is an echo number in a train, W is a wait time, TE_{long} is a diffusion editing

4   spacing, TE is the Carr-Purcell spacing, $90_{\pm x}$ and β_Y are RF pulses providing

5   rotation angles of 90^0 and the β of a magnetization vector.

6

1 31   (original) The apparatus of claim 20 wherein said processor further obtains an

2   equivalent amplitude spectrum of a T_2 distribution.

3

1 32. (currently amended) A system for use in a borehole in an earth formation

2   comprising:

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3   (a)   a conveyance device ~~for conveying~~ which conveys a nuclear magnetic

4   resonance (NMR) sensor into said borehole;

5   (b)   a magnet on said ~~NMR)~~ NMR sensor, said magnet applying a static

6   magnetic field in said earth , said static magnetic field having an internal

7   gradient;

8   (b)   a transmitter on said NMR sensor ~~for applying~~ which applies

9   radio-frequency (RF) magnetic field pulses to said formation and

10   ~~producing~~ produces signals resulting from a T_2 distribution spectrum of

11   said earth formation, at least one component of said T_2 spectrum further

12   comprising a plurality of diffusion coefficients, said signals being

13   substantially affected by the internal field gradient;

14   (c)   a receiver on said NMR sensor ~~for receiving~~ which receives said produced

15   signals;

16   (d)   a processor ~~for processing~~ which processes said received signals and

17   ~~determining~~ determines therefrom said T_2 distribution and said plurality of

18   diffusion coefficients, said determination accounting for said internal

19   gradient.

20

1 33.   (original) The system of claim 32 wherein said conveyance device is one of (i) a

2   wireline, (ii) a drillstring, and, (iii) coiled tubing..

3

1 34.   (currently amended) A method of analyzing an earth formation comprising:

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2   (a)   applying a static magnetic field to the earth formation, said applied

3   static magnetic field producing an internal field gradient in said earth

4   formation;

5   (b)   applying a first sequence of radio frequency (RF) pulses to said earth

6   formation and obtaining a first signal associated with a first value of a

7   field gradient;

8   (c)   applying a second sequence of radio frequency (RF) pulses to said earth

9   formation and obtaining a second signal associated with a second value of

10   a field gradient; and

11   (d)   processing said first and second signals for determining at least one of (A)

12   a diffusion characteristic of said earth formation, and, (ii) a relaxation

13   characteristic of said earth formation, said determination taking into

14   account said internal field gradient;

15   <u>wherein said first and second signals being substantially affected by the internal</u>

16   <u>field gradient.</u>.

17

1   35.   (original) The method of claim 34 wherein said first and second field gradients

2   correspond to different regions of examination in said earth formation.

3

1   36.   (original) The method of claim 34 said first and second pulse sequences each

2   comprise at least one initial pulse, a first portion that follows the at least one

3   initial magnetic field pulse, and a second portion that follows the first portion

4   such that the second portion refocuses a last echo of the first portion.

5

1   37.   (currently amended) An apparatus for use in a borehole in an earth formation

2   comprising:

3   (a)   a magnet for applying which applies a static magnetic field to the earth

4   formation, said applied static magnetic field producing an internal field

5   gradient in said earth formation;

6   (b)   a transmitter for applying which applies a first pulse sequence and a

7   second sequence of radio frequency (RF) pulses to said earth formation;

8   (c)   a receiver for obtaining which obtains a first signal and a second signal

9   resulting from said first and second sequence of RF pulses, said first and

10   second signals associated with a first and second value of a field gradient

11   in said earth formation and affected by the internal field gradient; and

12   (d)   a processor for determining from said first and second signal at least one

13   of (A) a diffusion characteristic of said earth formation, and, (ii) a

14   relaxation characteristic of said earth formation, said determination taking

15   into account said internal field gradient.

16

1   38.   (original) The apparatus of claim 37 wherein said first and second field gradients

2   correspond to different regions of examination in said earth formation.

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1   39.   (original) The apparatus of claim 37 said first and second pulse sequences each

2   comprise at least one initial pulse, a first portion that follows the at least one

3   initial magnetic field pulse, and a second portion that follows the first portion

4   such that the second portion refocuses a last echo of the first portion.

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1   40.   (original) The apparatus of claim 37 further comprising a conveyance device

2   selected from (i) a wireline, (ii) a drilling tubular, and, (iii) coiled tubing.

3

1   41.   (original) The method of claim 39 wherein said first portion comprises one of (i)

2   an inversion recovery sequence, (ii) a driven equilibrium sequence, (iii) a CPMG

3   sequence, and, (iv) a modified CPMG sequence having a refocusing pulse with a

4   tipping angle less than 180°.

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